

2MASS J01074282+4845188: a new nova-like cataclysmic star with a deep eclipse

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Abstract

We present *VRI* photometry and low-resolution spectroscopy of the object 2MASS J01074282+4845188. The V-shape of the eclipse, the phase variability of the colour indices as well as the presence of a pre-eclipse hump, stand-still and flickering allow us to conclude that it is a nova-like cataclysmic star. This is supported by the observed broad emission H α line. Its single profile with a relatively narrow FWHM but large FWZI is typical for a nova-like variable of SW Sex subtype. The observed deep eclipses make the newly discovered cataclysmic star 2MASS J01074282+4845188 an interesting object for future investigation.

Keywords: binaries: eclipsing, binaries: close, cataclysmic variables, stars: individual: 2MASS J01074282+4845188

1. Introduction

Many large photometric surveys were recently published: OGLE-III (Udalski, 2003), ASAS (Pojmanski, 2002), NSVS (Wozniak et al., 2004), HATnet (Bakos et al., 2004), TrES (Alonso et al., 2004), SuperWASP (Pollacco et al., 2006), *CoRoT* (Baglin et al., 2002), *Kepler* (Borucki et al., 2010), etc. After reaching the survey's original purpose, the huge photometric data-sets collected by these surveys were released for the community and allowed to extract (as a by-product) a great number of light curves of known and newly discovered vari-

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Table 1: Journal of the photometric and spectroscopic observations

Date	Filter	Exp. [s]	N	Telescope
2011 Jan 29	<i>V, I</i>	120, 120	67, 67	60-cm
2011 Jan 30	<i>V, I</i>	120, 120	65, 65	60-cm
2011 Jan 31	<i>R</i>	60	222	60-cm
2011 Feb 07	spectra	300	4	2-m

able stars. Some of them were objects of study using automated pipelines but only a small part of them were targets of follow-up by precise observations and analysis.

Searching for binary systems for follow-up observations with periods below 0.23 d in the photometric surveys we noted the object T-And0-10518 in the list of 773 eclipsing binaries (Devor et al., 2008) found on the basis of the TrES data. It was classified as "ambiguous EB" with coordinates $\alpha=01^{\text{h}}07^{\text{m}}44^{\text{s}}.417$ and $\delta=+48^{\circ}44'58''.11$. Its period of 0.1935761 d (see table 6 of Devor et al., 2008) fulfills our criterion for a short-period binary appropriate for follow-up observations. We began these at the beginning of 2011 and found this binary to be a new nova-like system.

The paper presents the results from this study.

2. Observations

Our CCD photometric observations in *VRI* bands were carried out at Rozhen National Astronomical Observatory with the 60-cm Cassegrain telescope using the FLI PL09000 CCD camera (3056 x 3056 pixels, 12 μm /pixel, field of 27.0 x 27.0 arcmin with focal reducer). The average photometric precisions per data point in B, V and I bands are 0.020, 0.010 and 0.008 mag respectively.

The spectra of the target were obtained by the 2-m RCC telescope equipped with VersArray CCD camera (512×512 pixels, 24 μm pixel, field of 6×6 arcmin) and focal reducer FoReRo-2. The resolution of our spectra is 5.223 Å/pixel and they cover the range 5000–7000 Å using a grism with 300 lines/mm.

Table 1 presents the journal of our observations.

The standard IDL procedures (adapted from DAOPHOT) were used for reduction of the photometric data. For transition from instrumental system to standard photometric system we used standard stars of Landolt (1992) and standard fields of Stetson (2000). The standard stars in the observed

Table 2: Colours of the target and standard stars

Star	ID	V	$B - V$	$V - R$	$V - I$	$J - K$
	GSC1.2(2.3)	[mag]	[mag]	[mag]	[mag]	[mag]
Var	NBVX029228	14.94	0.22	-0.01	0.48	0.46
St1	3268-0055	11.98	0.20	0.08	0.64	0.19
St2	3268-0507	12.95	0.84	0.47	1.42	0.20
St3	3268-0083	13.16	0.28	0.14	0.74	0.35
St4	3268-0735	12.79	0.74	0.24	0.94	0.39
St5	3267-1164	12.77	0.36	0.14	0.73	0.25
St6	3268-0459	12.95	0.49	0.21	0.88	0.29
St7	3272-0364	12.28	0.31	0.14	0.72	0.25
St8	NBVX029156	13.73	0.47	0.19	0.82	0.29

field (Fig. 1) were chosen by the criterion to be constant within 0.005 mag during the all observations and in all filters. Table 2 presents their colours V , $B - V$, $V - R$ and $V - I$ determined by our observations (for the target they correspond to phase 0.25 of the out-of-eclipse light) as well as $J - K$ colours from the 2MASS catalog (Skrutskie et al., 2006).

Our photometric observations revealed that the coordinates of T-And0-10518 given by Devor et al. (2008) belong to the non-variable star 2MASS J01074441+4844581 marked by St8 in Fig. 1. It turned out that the true variable star (marked with Var in Fig. 1) with a period of around 0.19 d is the object 2MASS J01074282+4845188. It is at a distance of nearly 26 arcsec from St8 and it is around 3 times weaker than St8. To escape the future misunderstanding we will use further the name 2MASS J01074282+4845188 for the target.

With the periodogram analysis of all our photometric data performed by using the PERSEA software (written by G. Maciejewski, www.astr.uni.torun.pl/~gm/software.html) based on ANOVA technique (Schwarzenberg-Czerny, 1996) we derived period of 0.1935972 d. This value is slightly bigger than that in the table 6 of Devor et al. (2008). Actually, their table contains two periods: 0.1935761 d (assuming an unseen secondary eclipse) and the double value 0.3871522 d (assuming equal eclipses).

The Rozhen' photometric observations were phased according to the period derived by us. Figure 2 presents the corresponding folded curves in V , R , and I filters.

The reduction of the spectra was performed using IRAF packages by bias subtraction, flat fielding, cosmic ray removal, one-dimensional spectrum extraction and wavelength calibration. The spectra of the target are presented in Fig. 3.

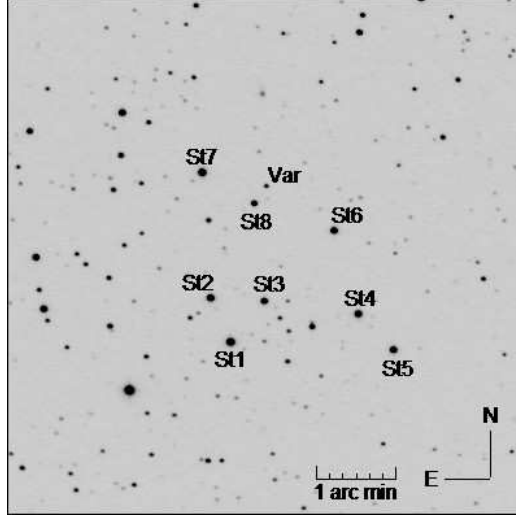


Figure 1: The field with the true variable marked as Var and T-And0-10518 marked as St8

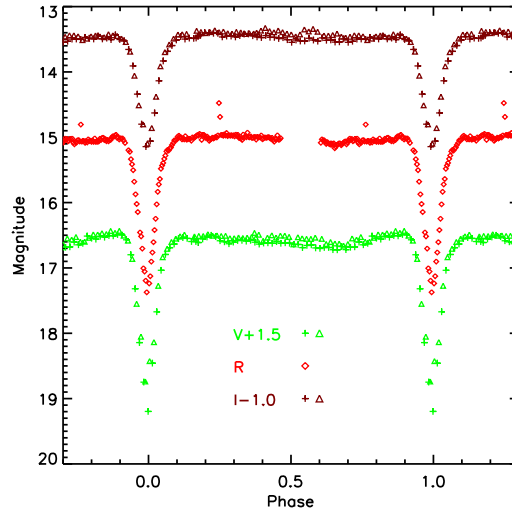


Figure 2: The *VRI* light curves of 2MASS J01074282+4845188 from Jan 2011. The used symbols are: pluses for the data from 2011 Jan 29; triangles for the data from 2011 Jan 30, and diamonds for the data from 2011 Jan 31.

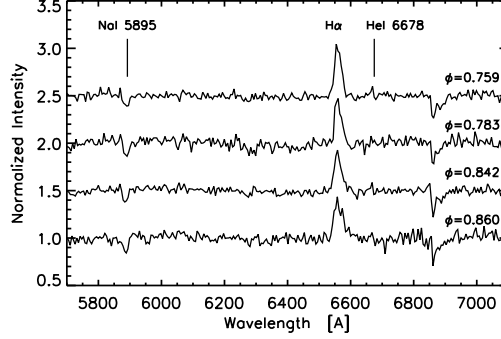


Figure 3: The low-resolution spectra of 2MASS J01074282+4845188 from 2011 Feb 07

In order to compare our photometry with the previous one we exhibit in Fig. 4 (top panel) the TrES data (phase, differential magnitude) of T-And0-10518 from the VizieR database.

Moreover, we checked if there are photometric observations of 2MASS J01074282+4845188 in the SuperWASP data-set (Butters et al., 2010). The result was negative. However, using for identification the coordinates of 2MASS J01074441+4844581 (or T-And0-10518, named in the SuperWASP as 1SWASP J010744.41+484458.1) we managed to download the photometric data of which periodogram analysis led to the ephemeris

$$HJD(MinI) = 2454417.382244 + 0.1935980 \times E. \quad (1)$$

The light curve (Fig. 4 bottom panel) on the SuperWASP data looks the same as the TrES light curve and their periods are almost equal. This means that the SuperWASP survey has made the same misidentification of the variable star as the TrES survey probably due to the same reasons: low spatial resolution of the observations causing considerable blending from the nearby brighter star and automatic reduction of data.

3. Analysis of the Rozhen' observations

3.1. Analysis of the new photometric data

The Rozhen' light curve of 2MASS J01074282+4845188 has one deep, asymmetric, V-shaped, light minimum. Such type of minima are typical for the cataclysmic nova-like stars and they are attributed to eclipses of their accretion disks.

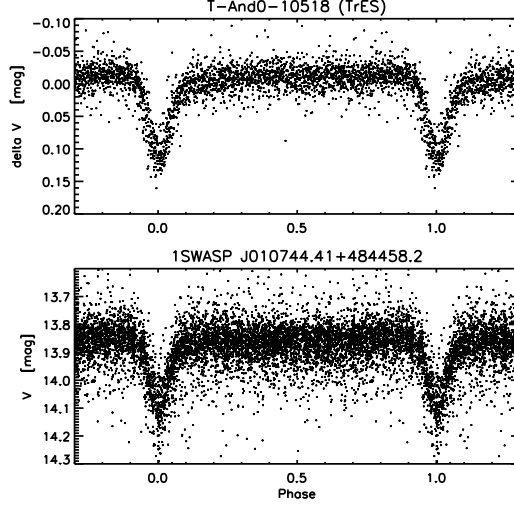


Figure 4: Top: The TrES light curve of T-And0-10518 (original data); Bottom: Light curve from the SuperWASP photometry

We found several peculiarities of the Rozhen' light curve of the target that support our suspicion that this system is nova-like.

(a) There is a standstill on the increasing branch of the light minimum. Such a feature is present on the light curves of eclipsing cataclysmic stars and it is attributed to hot spot on their accretion disks.

(b) There is a pre-eclipse hump (most visible in V colour) on the Rozhen light curve, another feature typical for the eclipsing cataclysmic stars, that is also attributed to the emission of the hot spot.

(c) There is broad and shallow light decrease on the Rozhen' curves (especially in V colour) centered at phase 0.65 (Fig. 2) shape and depth of which are variable. Such a feature is hardly visible on the SuperWASP light curve.

(d) The colour index $V - R$ changes during the cycle reaching an extreme value of -0.01 mag for the out-of-eclipse light (phase 0.25) and 0.33 mag for the minimum light (phase 0.0). The colour index $V - I$ reaches an extreme value of 0.48 mag for the out-of-eclipse light (phase 0.25) and 1.56 mag for the minimum light (phase 0.0). Such a variability of the colour indices indicates that the star becomes bluer out of the eclipse and redder in the middle of the eclipse. This means that the emission of the eclipsed component at phase 0.0 (probably an accretion disk covered by a late-type star) is strongest in V

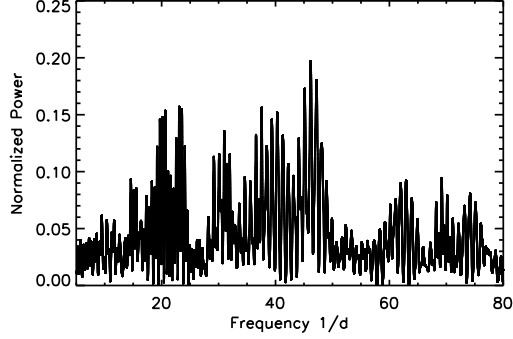


Figure 5: Periodogram analysis of 2MASS J01074282+4845188

band.

(e) In order to search for flickering, another important characteristic of the CVs, we made periodogram analysis of the Rozhen' photometric data. For this aim we excluded the points of the deep light minima (between phases 0.91 and 1.09). Moreover, the out-of-eclipse data were de-trended in order to escape a variability related with the orbital period (light decrease around the phase 0.65). As a result we obtained the periodogram shown in Fig. 5. The figure shows variability at many frequencies, as is typical for flickering.

Hence, our target has got all important photometric appearances of cataclysmic nova-like eclipsing variable. Its period' value is also appropriate for CVs.

Using the empirical relation "period – absolute magnitude" for the nova-like stars (Warner, 1995) we obtained for 2MASS J01074282+4845188 absolute magnitude $M_V=4.5$ mag and distance $D = 1260$ pc.

3.2. Analysis of the spectra

The Rozhen' low-resolution spectra of 2MASS J01074282+4845188 (Fig. 3) reveal that the most noticeable spectral feature in the observed range is the $H\alpha$ line which profile is typical for a cataclysmic star.

(a) The $H\alpha$ line is in emission. Its big width corresponds to the high rotational velocity of an accretion disk.

(b) The profile of the $H\alpha$ line changes rapidly in the framework of our short observational run (see Fig. 3 and Table 3): (i) the EW varies between 11.4 and 13.8 Å; (ii) the FWHM ranges between 23.7 and 33.5 Å; (iii) the FWZI varies between 58 and 84 Å; (iv) the normalized intensity changes between 1.43 and 1.55. Such parameters of the $H\alpha$ line are typical for the

Table 3: Parameters of the H α line

spectrum	HJD 2455000+	phase	λ_c [Å]	FWHM [Å]	FWZI [Å]	EW [Å]	Intensity
1	600.21450	0.759	6559.7	24.9	68.0	13.8	1.55
2	600.21919	0.783	6560.0	23.7	57.5	11.8	1.47
3	600.23052	0.842	6559.1	26.8	73.2	11.4	1.43
4	600.23403	0.860	6561.4	33.5	83.7	13.8	1.43

accretion disks of CVs. The observed fast changes of the H α profile may due to inhomogeneity of the accretion disk.

(c) The H α profile is asymmetric which may be explained by asymmetry of the accretion disk.

(d) H α shows an "inverse P Cyg" profile at phases 0.783 and 0.842 as well as double-peaked core at phase 0.86 at which its FWHM increases considerably.

(e) The H α line is blue-shifted by around 125 km/s (see the third column of the Table 3 containing the wavelength λ_c of the center of the profile). Taking into account that our spectral observations were around the second quadrature of the binary we attributed this Doppler shift to the orbital motion of the H α emission source.

Besides the emission in the H α line, weak emission is visible in the HeI 6678 line on some of our spectra (Fig. 3).

The foregoing results should be considered as preliminary due to the low S/N of the presented spectral observations and their poor phase covering.

3.3. The subtype classification of 2MASS J01074282+4845188

The criteria for the subtype classification of the nova-like stars are not firm and a given star may belong to several subtypes (Warner, 1995). We tried to determine the subtype of 2MASS J01074282+4845188 on the basis of several considerations.

(a) The presence of broad H α emission excludes its classification as a UX UMa subtype.

(b) The single-peaked shape of the H α emission line and its fast variability are typical for SW Sex-subtype stars.

(c) The FWHM and FWZI of the H α line fall into the ranges for SW Sex stars for which Balmer and HeI emission lines have a relatively narrow FWHM (around 1000 km s⁻¹) but large FWZI (2000-3000 km s⁻¹).

(d) The SW Sex stars are intrinsically very luminous due to high mass transfer rate. 2MASS J01074282+4845188 is also a quite luminous source

($M_V=4.5$ mag).

(e) Although the orbital period of 4.65 h of the target is slightly above the period' range 3 – 4.5 h for most SW Sex subtype stars it does not exclude the SW Sex-subtype classification of 2MASS J01074282+4845188 because there are several other exceptions from this criterion (see table 6 in Rodriguez-Gil et al. (2007)).

Hence, the Rozhen' data directed us to SW Sex-subtype classification of 2MASS J01074282+4845188. Due to the lack of prolonged photometric observations and high-resolution spectra we are not able to check the further criteria of this subtype classification.

The depth of the light minimum of the Rozhen curves (Fig. 2) is 2.7 mag in V band while the light amplitudes of TrES and SuperWASP light curves (Fig. 4) are considerably smaller. The situation is very similar to the false positives of exoplanet' candidates in the TrES survey (for instance exoplanet candidate T-Cyg1-14777, see Fig. 5 in Dimitrov, 2009).

It should be noted that among around 2000 known cataclysmic stars only several hundred are nova-like and only several tens of them are eclipsing. Usually the eclipse depths of nova-like variables are ≤ 1 mag. The deepest eclipses belong to the SW Sex' stars. Only nine SW Sex' stars in the list of Rodriguez-Gil et al. (2007) have eclipse depths above 2.0 mag but smaller than that of 2MASS J01074282+4845188 (2.7 mag). Deeper eclipses of 3.2 – 3.4 mag have been registered for two SW Sex' stars, DW UMa (Stanishev et al., 2004) and V1315 Aql (Papadaki et al., 2009), but only during time intervals of 2 – 3 days whereas normally their eclipse depths are below 2.0 mag. Thus our study not only added a new member to the small family of eclipsing nova-like stars but 2MASS J01074282+4845188 turned out to have one of the deepest eclipses. It is possible for the big depth of its eclipse to be transient effect as in the cases of DW UMa and V1315 Aql.

4. Conclusion

The main results of our investigation are:

- (1) The V-shape of the eclipse, the phase behaviour of the colour indices as well as the presence of standstill, pre-eclipse hump and flickering allow us to conclude that 2MASS J01074282+4845188 is a nova-like cataclysmic variable.

- (2) The broad emission $H\alpha$ line of 2MASS J01074282+4845188 is typical for a fast-rotating accretion disk of the nova-like cataclysmic stars. The single $H\alpha$ profile with a relatively narrow FWHM but large FWZI is typical for the SW Sex subtype of the nova-like variables.
- (3) The deep eclipses observed at the beginning of 2011 make the newly discovered cataclysmic star 2MASS J01074282+4845188 an interesting object for future observations and investigation.

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